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Analysis of crowd behavior through pattern virtualization.

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Abstract

The study of the concentration of individuals in public places such as squares, shopping malls, parks, gardens, etc., is an open study field in the different disciplines of science, that leads to the need of having systems that allow to forecast and to predict eventualities in uncontrolled situations, as it is the case of an earthquake. From that assumption, artificial intelligence, as a branch of computational sciences, studies the human behavior in a virtual way in order to obtain simulations based on social, psychological, neuro-scientific areas, among others, with the purpose of linking these theories to the area of artificial intelligence. This paper presents a way to generate virtual multitudes with heterogeneous behaviors, in such a way that the individuals that form the multitude present different behaviors.

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1. Introduction

The study of the concentration of individuals in public places such as squares, shopping malls, parks, gardens, etc., is an open field of study in the different disciplines of science. This scenario requires systems that allow for the prediction of contingencies in uncontrolled situations, such as earthquakes [1]. In order to respond to this reality, the computational sciences, specifically artificial intelligence study the way to replicate the human behavior virtually, to make simulations based on social, psychological, neuroscientific areas, among others, with the purpose of linking

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these theories to the field of the artificial intelligence [2].

The main purpose of studying and simulating virtual crowds is to accurately represent groups of autonomous individuals called virtual agents who attend to the same rules in environments close to those found in real life [3]. In order to anticipate contingencies and attend them adequately before they happen, it is necessary to study the behavior of masses of individuals in daily activities, allowing the construction of the required infrastructure according to the needs of the individuals, for the development of what is now known as smart cities, which include de design of spaces for human beings such as squares, airports, schools, public transportation, etc. [4].

Research groups around the world have joined the problem of virtual crowd simulation with great achievements from the realism obtained to the behavior embedded in virtual agents. However, their simulations lack heterogeneity in the population since their studies are focused on a single model that they replicate infinitely in the virtual environment, which is less computationally costly compared to the generation of diverse models according to the heterogeneity of the population and implies that the behavior observed within the simulation is identical for all virtual agents [5].

In reality, there is not a determined number of individuals that constitute a multitude, however, the study of multitudes is based on the greatest number of individuals concentrated in one space observing their behavior in situations of stress, maintaining the goal of being able to anticipate contingencies in real time [6]. The computational approaches for the generation of crowds are centered on the rules of the physical environment and the behavior is based on the interaction with the environment and its physical rules [7].

One of the problems with generating crowds is the visual diversity to represent the heterogeneity in the crowds, as well as the planning that the agents must develop within the virtual environment to achieve their objectives [8].

In order to successfully reproduce individual and group behavior, two fundamental problems must be addressed: planning and decision-making. Planning will equip agents to observe the environment and to be able to decide on the conditions of the environment, for example collision avoidance. The main methods for collision avoidance are based on social forces [9], while speed is managed in a way that is the same for all actors. A simple algorithm for collision avoidance compares the position of each agent with the others, however, as the number of agents (denoted by N) grows, the complexity of the algorithm is O(N2) [10]. This complexity represents a problem when large crowds must be simulated, making impossible to obtain a simulation in real time. For a crowd simulation to be accurate, it is necessary to reproduce individual and group human behaviors, and the algorithms that synthesize these behaviors must be optimized to work in real time [11].

2. Generation of heterogeneous behaviors

One problem to be addressed in crowd generation is its lack of diversity, because only one model of the agent is used that is replicated in a discriminated way, changing only the color of clothing or hair [12]. Besides, the lack of autonomy in the agents causing a single behavior reduces the realism in the simulation. The proposal of the study is based on the generation of heterogeneous multitudes through diverse models that conform the multitude without neglecting the behaviors associated to each agent, for example, if there is an old man in the scene, who must have the behavior of an old man [13].

2.1 Human behavior

The behavior of each person in real life is unique, and is determined by an endless number of factors that determine it over time, as well as the experiences lived by each person. It is also defined by physiological aspects and capacities that prevent certain sectors of the population from performing certain activities [14].

The ideal in the crowd simulations is that each agent will behave differently just as they do in real life. However, this process would take too many system resources for each virtual agent to show an individual behavior making impossible its simulation in real time.

In [15], the travel speed, step cadence and stride length of people were determined, taking into account parameters such as age, weight and height of people. To do this, the researcher analyzed 118 women and 121 men in a range of 19 to 90 years of age, who walked at their preferred speed as they usually did through a 12-meter footbridge. [15] proposes some formulas to calculate the speed of movement of individuals in everyday activities. In the case study the equations proposed by Samson were re-applied so that the virtual agents reproduce these displacements with the characteristic that distinguish men and women within the simulation. Table 1 shows the relationship between the speed of displacement of men and women.

Table 1. Samson's human displacement velocity equations in meters/seconds [15].

Men
Speed = 1460
Speed = -0.002 age (*) + 1.582
Speed = -0.002 age (*) + 0.442 height (*) + 0.750
Speed = -0.001 age (*) + 0.486 height (*) - 0.001 weight (*) + 0.720
Women
Speed = 1,420
Speed = -0.003 age (*) + 1.552
Speed = -0.002 age (*) + 0.618 height (*) + 0.484
Speed = -0.001 age (*) + 0.827 height (*) - 0.003 weight (*) + 0.316

The possibility of providing the agents with random values in the displacement, as well as mass and height conditioners, allows to obtain a simulation within the crowd as close as possible to reality. The factors associated to the physics of the environment are emerging behaviors according to the different masses of the agents that participate in the simulation. The agents are provided with sensors that allow them to recalculate their trajectories to avoid collisions with objects within the environment and with other agents. In a multiagent system, the environment is defined as the set E = {e,e0,...} where E is the environment formed by all the possible states. Ac = {α,α0,...} represents all the actions allowed within E. The agents build their knowledge base from r: e0 α 0 → e1 α 1 → e2 α 2 → e3 α 3→--- α u-1 → eu that represent the actions performed from one state to another within E [16].

2.2 Spatial geometric distribution of the environment

The environment geography is an important factor in the generation of crowds. The virtual agents that will occupy the space should have initial information that allows them to recognize their environment and to achieve their objectives, and know which places are those that can visit and those that should be avoided. To solve this issue, Voronoi diagrams are used in order to divide an area into well-defined regions. If P = {p1,p2,...,pn} is a set of points in the plane, using the Voronoi diagram, it is possible to assign each point a region in the plane corresponding to the closest points, a region for each pi ∈ P, all the points assigned to pi in the set of points P form the Voronoi region V (pi) [3]. Given a set of points in P and a query point q, it is possible to determine the point closest to q in P, since the location of q is within a Voronoi region in a point pi which indicates that point pi is the closest to point q [14] [16].

$$V(p_i)=q \parallel p_i q \parallel < \parallel p_j q \parallel ,\forall j \neq i \quad (1)$$

Where ‖pq‖ is the Euclidean distance between p and q.

As a first approach, it can be stated that given a set P of sites (points) on the plane, its Voronoi diagram is the partitioning of that plane into regions (a region for each site), such that the region of the site p contains all the points of the plane that are closer to p than to any other site on P.

This case study makes use of the Steven Fortune algorithm to generate the Voronoi diagram since this algorithm [5] is executed in O (n log n). Once the Voronoi diagram is generated, it is used to determine the correct distribution of the population within the virtual environment. The first results correspond to a simulated citadel (see Figure 1), where the p-points generated by Voronoi will be called population concentration places (PCP). A PCP can be a bus stop, a commercial store, etc. The use of PCP allows to conceptualize the spaces within the environment and to be able to define the concentration of individuals by regions. For example, if the region is marked as a primary school, this region should be mostly populated with agents representing children in an age range between 6 and 12 years.

The possibility of having several PCPs will allow to populate much more complex environments and be able to observe and study the associated and emerging behaviors within a completely heterogeneous population.

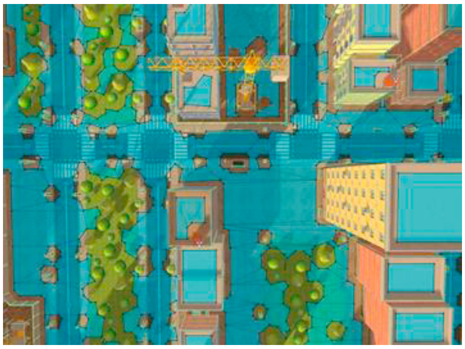

Fig. 1. Location of PCP within the environment.

3. Results

The software used for the agent simulations was Unity 5.3 64 bits, in a computer with intel i7 3.4GHz processor and 4 GB in RAM. The first results obtained are based on the displacements that the agents take inside the virtual environment where it is possible to distinguish heterogeneous displacements. Initially the agents are represented by cubes of different sizes and masses to provide them with individual characteristics.

The agents are identified by color to classify them in 5 types of roles within the environment. The green ones represent the population of children between 4 and 14 years old, the blue ones represent young people between 15 and 24 years old, the red ones represent adults between 25 and 54 years old, the violet ones represent adults between 55 and 64 years old, and finally, the brown ones represent the elderly people over 65 years old. Figure 2 shows the representation of the agents populating the virtual environment.

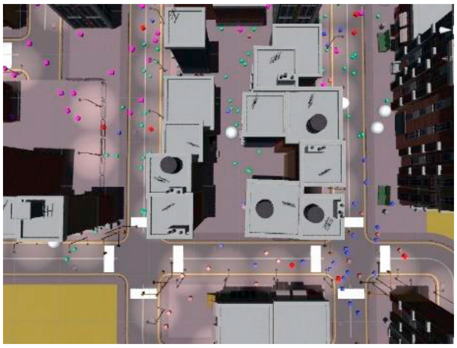

Fig. 2. Virtual agents, moving around the city looking for their PCP of interest.

The implementation of the speed equations proposed by Samson allows to observe natural type displacements. Besides the creation of the LCP, the agents have the possibility to take different paths occupying all the geographical space of the environment allowing to achieve behaviors similar to the real ones.

Figure 2 shows the simulation of the agents moving through the streets of the city, towards their target PCP. It can be noted how the agents consider the rest of the agents within the environment avoiding collisions with others. It is also possible to see that an important mass of agents starts to accumulate trying to access the resource, which produces saturation in certain areas. The PCPS allow to concentrate agents of the same type, however, it is valid to find agents of another type in the same area, this is due to the routes that the agents take and they are similar behaviors to the ones seen in the reality. Finally, the emergence of behaviors such as the grouping of crowds results from the need to access a resource, as it happens in the reality.

Figure 3 shows the patterns obtained by the agents, it is important to emphasize that the distance between agents is not given, otherwise the final result would be a military type formation (aligned), which does not happen in the behavior of a real population of civilians.

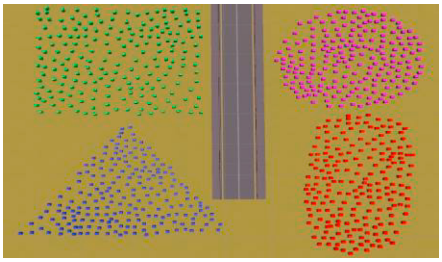

Fig. 3. Crowd patterns obtained by agents

In many of the demonstrations involving crowds of people, they gather in small groups and join with others to reach the final goal. These little groups must overcome various obstacles to reach the larger contingent, in the next test as an experiment, two groups of crowds with different patterns are integrated to observe how the integration is done in a single group and what pattern is obtained as a result. This behavior is observed in Figure 4. At the moment they begin the displacement, they break the initial pattern and once the new group is formed a pattern is maintained in a square shape when it is a displacement and in a circular or ovoid shape in the case of waiting. The delta pattern is formed in the presence of a leader agent to be followed.

In the video 1 of the web, two experiments can be observed, where the agents move to their objectives negotiating spaces and calculating their routes, also in the same video, the integration of the two multitudes that are shown in the Figure 4 can be observed.

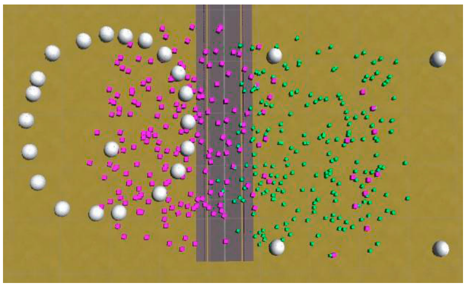

Fig. 4. Crowd patterns obtained by agents.

4. Conclusions

The use of human travel speeds used in crowd simulations allows to observe the behavior similar to real life. The categorization of individuals by age generates indistinct behaviors, which allows to observe, in the simulation, behaviors as close as possible to reality. One of the contributions made in this study is the creation of PCPs using Voronoi diagrams, which allows to generate concentrations of individuals in a space that the agents need to access as a resource, as well as to see how the agents carry out communication and negotiation processes to achieve their individual objectives. The identification of PCPs allows to observe heterogeneous concentrations of agents according to a context. For example, a park should be mostly populated by elders, children and women. Being able to reproduce the patterns of the groupings of the crowds with the virtual agents allows to study the behaviors as they happen in real life, allowing the organizations to evaluate the conditions for implementing policies for possible contingencies.

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